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Fatty Acids Composition of Meat of Five Native Chicken (*Gallus gallus*) Ecotypes of Benin Reared under Organic or Conventional system

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Abstract

The current study aims to determine the composition in fatty acids of 5 native chicken ecotypes of Benin reared under organic or conventional system. It appears that the predominant Fatty Acids (FA) in chicken meat of all treatments were palmitic and stearic (18:0) acids as Saturated Fatty Acid (SFA), oleic acid as Monounsaturated Fatty Acids (MUFA), Conjugated Linoleic Acid (CLA) and 20:3 n-3 as Polyunsaturated Fatty Acids (PUFA). The highest SFA, MUFA and PUFA contents were found respectively in Holli, Fulani and North ecotypes ($P<0.05$). The highest n-3 PUFA content (3.8%; $P<0.05$) was found in Holli chickens. The weakest ratio n-6/n-3 PUFA was found in North chickens. As for the rearing system, the highest MUFA content was recorded in chicken reared under organic system ($P<0.05$). The breast meat showed higher n-3 PUFA concentration and lower ratio n-6 PUFA/n-3 PUFA than thigh meat ($P<0.001$). Overall, native chicken of Benin and organic system can ensure additional health benefit for consumers.

Keywords: Benin; Organic system; Indigenous chicken; Ecotype, Fatty acids profile

Introduction

In Benin, domestic local chicken (*Gallus g. domesticus*) represents the main avian genetic resources [1,2]. The national poultry livestock in 2011 reported by Country STAT [3] is estimated to 17087,000 birds, with 81.3% of indigenous chickens for 6000,000 inhabitants.

This indigenous chicken population is from a slow-growing type with relatively low carcass weight [4] and is reared mainly for meat production. In spite of this important livestock amount, local production of poultry meat remains below the consumer demand. Therefore, poultry meat imports increased 2.5-times from 2000 to 2010 [3]. However, local chicken meat is preferred by consumers comparatively to imported frozen chicken meat [5].

The local population of poultry of the species *Gallus gallus* of Benin is composed of various ecotypes among which are North, South, Holli, Fulani (or Peuhl) and Sahoue ecotypes [4]. These indigenous chicken populations have a great heterogeneity in phenotypical traits [6] and polymorphism trait [7]. Several works were done on carcass traits of these local genetic types [7,8,4]. The recent works carried out on carcass composition [4] and technological meat quality of these five ecotypes of local chickens of Benin by breeding mode and slaughter age [9,10] showed that important differences exist in meat quality among genotype, breeding mode, slaughter age and type of muscle. Moreover, the chemical composition of these local chicken meats was also affected by those factors [10].

If the difference between the five ecotypes of local chicken is well known as far as phenotypical traits, polymorphism traits, carcass composition, technological quality of meat and nutritional quality of meat are concerned, any knowledge exists on the fatty acids profile of their meat fat. Fat contains different types of fatty acids and their profile can be affected by several factors such as genetic type [11-13], feed composition [14,15] production system [16], and type of muscle [17,18]. Furthermore, since some fatty acids can provide many health benefits (foetal development, heart diseases), it is useful to determine the fatty acids profile of these 5 ecotypes of chickens in relation with breeding system and type of muscle.

The present study aims specifically to determine the fatty acids profile of meat fat from North, South, Holli, Fulani and Sahoue chicken ecotypes of Benin in relation with their breeding system and type of muscle.

Material and Methods

Area of study

The current study was conducted conjointly at the experimental farm of "Ecole Polytechnique d'Abomey-Calavi (EPAC)" (Figure 1) and at the traditional organic poultry breeders located in Abomey-Calavi in Atlantic Department from April 2011 to June 2012. Situated at latitude of 6°27' north and at a longitude of 2°21' east, the Commune of

Abomey-Calavi covers an area of 650km² with a population of 307,745 inhabitants [19]. The exhibits climatic conditions of this area were given by Tougan et al. [4].

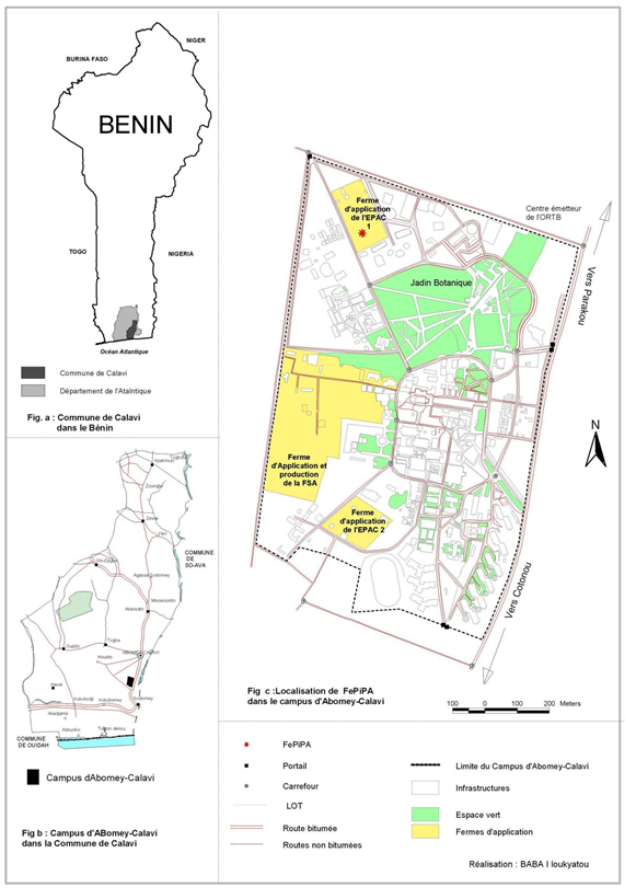

Figure 1: Study area

Birds sampling and slaughtering process

The chickens used in this trial were produced from breeding nuclei of 10 hens and 3 cocks of each genetic type (North, South, Holli, Fulani and Sahoue), reared in confinement at the experimental farm of EPAC as described by Tougan [4]. Two groups of 26 chickens of each ecotype were reared respectively under traditional organic free range and conventional confinement breeding systems until 28 weeks old and then slaughtered. The characteristics of both breeding systems used were described by Tougan et al. [4].

The slaughtering process used was described by Tougan et al. [4]. The choice of birds was based on body weight. The first 5 birds whose live weight was heavier than the mean and the first 5 birds whose live weight was weaker than the mean were selected. Then, a total of 26 cocks of each breeding mode were selected per genetic type for slaughtering. The cuts of breast and thigh-drumstick were used to evaluate the fatty acid composition of meat.

Birds sampling and characteristics of breeding systems (organic free range *vs* conventional confinement breeding system)

The chickens used in this trial were produced from breeding nuclei of 10 hens and 3 cocks of each genetic type (North, South, Holli, Fulani and Sahoue), reared in confinement at the experimental farm of EPAC as described by Tougan et al. [4]. Two groups of 26 chickens of each ecotype were reared respectively under traditional organic free range and conventional confinement breeding systems until 28 weeks old and then slaughtered. The characteristics of both breeding systems used were described by Tougan et al. [4]. In short, in organic free range system, the birds were let scavenge during the day but housed at night as in traditional poultry farming. The feeding is not rational and the birds fed themselves by gleaning, but, some grain supplement was distributed to birds occasionally [4]. Their diet was composed of energetic elements (kitchen waste, bran and sorghum), vitamins (green fodder, sprouted grains), minerals (salt and pounded shells) and protein from termites and leguminous plants [20]. Water was distributed in rudimentary watering tank. Various discarded containers were often used for drinking. In this type of farming, no health follow-up or prophylactic standard was applied [4].

Concerning conventional confinement breeding system, the birds were bred on a fresh wood shavings litter in buildings of California type. The livestock equipment used was composed of brooders, feeders, drinkers and perches. The number of these devices depended on the number of birds in the henhouse. All the animals were fed with the same diet. Three diets were used: starting (2880 ME Kcal/kg and 18% of crude protein), growing (2969 ME Kcal/kg and 18% crude protein) and laying (2800 ME Kcal/kg of feed and 20% of crude protein). The starter feed was used from the hatching to the age of 2 months and the growth feed from 2 month old to the point of laying (22 weeks). From the point of laying to the end of the experimentation, the laying feed was used. The animals were fed ad-libitum throughout the study. Feed transitions were done during three days between the different growth periods by gradual incorporation to the previous diet with the respective proportions of 25%, 50% and 75% of the new diet [9]. Habitat, health and medical prophylaxis used in confinement breeding system were described by Tougan et al. [9].

Slaughtering process

The slaughtering process used was described by Tougan et al. [4]. The choice of birds was based on body weight. The first 5 birds whose live weight was heavier than the mean and the first 5 birds whose live weight was weaker than the mean were selected. Then, a total of 26 cocks of each breeding system (organic *vs* conventional) were selected per genetic type for slaughtering. The cuts of breast and thigh-drumstick were used to evaluate the fatty acid composition of meat.

Fatty acids analysis

Preparation of the samples and lipids extraction: Before extraction, meat samples without skin were homogenised an IKA A11 B cryogrinder and after freezing with liquid nitrogen with and then directly extracted using ultra-pure Chloroform: Methanol (2:1 v/v) mixture for 2 hours according to Folch et al.[21]. The volume of solvent was adapted according to the ratio 2 g of raw meat/100 ml of solvent mixture. The extract was transferred to a separation funnel and 20% (v/v) of NaCl 0.58% were added. After careful shaking, the mixture was let to separate and the recovered chloroformic extract was taken in a

phial and evaporated at 35°C under reduced pressure until dryness and weighed. Around 10 to 12 mg of crude lipids were then sampled and Fatty Acid Methyl Esters (FAME) was prepared by boron-trifluoride catalysed transesterfication. Briefly, 0.5 ml of pure n-hexane and 0.5 ml of reagent mixture made of n-Hexane: Methanol: Methanol-BF3 14% according to the respective proportion of 20%, 55%, 25% were added to the samples in pyrex tube, tightly sealed and then heated in water bath at 70°C during 90 minutes. Finally 0.2 ml of 10% aqueous sulphuric acid and 0.5 ml of saturated solution of NaCl were added, shaken and diluted in 8 ml of pure n-hexane before injection.

Gas liquid chromatography (GLC): Analysis of fatty acids methyl esters were performed by Agilent gas chromatograph equipped with an auto sampler, a flame ionisation detector and a fused silica capillary column of 30 m x 0.25 mm x 0.25 µm film thickness, Stabilwax-DA column from Restek. Chromatographic conditions were as follows: the temperature in detector was 250°C, and in the split/splitless injector, 250°C; the column temperature programme: from 50°C (1 min) to 150°C (at 30°C/min) than to 240°C (at 5°C/min) with a final hold of 5 min at 240°C. Helium at 1.5 ml/min was used as carrier gas. FAME was identified on the basis of their retention times compared with those of pure reference (Supelco 37-component FAME Mix-47885-U).

Confirmation of the different identifications was made by GC-MS analysis on 7975C apparatus with the same column and conditions (EI mode at 70 eV, Scanned mass range from 30 to 450 amu). The recorded mass spectra were compared with those of the WILEY 275.L data base. Each sample analysis was repeated twice.

Statistical analysis

The data collected on the fatty acids profile of meat from the five genetic types of chicken were analyzed with the software SAS [22]. For the analysis of variance, a fixed effects linear model was adjusted to the data and includes the fixed effects of genetic type, breeding system and type of muscle. The interactions between genetic type and breeding system, genetic type and type of muscle and breeding system and type of muscle, were significant and taken into account in the model of variance analysis. The mathematical expression of this model is as follows:

$Y_{ijkm} = \mu + E_i + BM_j + M_k + E^*M_{ik} + E^*BM_{ij} + BM^*M_{jk} + e_{ijklm}$, with:

Y_{ijkm}: mean performance of individual m, of ecotype i, of the breeding system j, and of the muscle k.

µ: average performance

E_i: fixed effect of ecotype i (Holli, Fulani, Sahoue, North and South)

BM_j: fixed effect of breeding mode j (traditional and improved)

M_k: fixed effect of muscle k (thigh-drumstick and breast)

E^*M_{ik}: Interaction between ecotype i and muscle k

E^*BM_{ij}: Interaction between ecotype i and breeding system j

BM^*M_{jk}: Interaction between breeding system j and muscle k

e_{ijklm}: Effect of random residual average performance of the individual m, of ecotype i, of the breeding mode j, of the muscle k and slaughter age l

The F test was used to determine the significance level of each effect in the model. Means were compared two by two by the Student's t test.

Results

Effect of the ecotype on fatty acid composition of meat

The fatty acid composition of meat revealed varying responses in the different genetic type investigated (Table 1). The predominant fatty acids in chicken meats of all treatments were palmitic and stearic (18:0) acids as Saturated Fatty Acid (SFA), oleic acid as Monounsaturated Fatty Acid (MUFA), and Linoleic Acid (LA) and arachidonic acid as Polyunsaturated Fatty Acid (PUFA). Palmitic and oleic acids were the most abundant fatty acids in the various meats under analysis.

The saturated fatty acid content differed significantly among genotype ($P<0.05$) and varied from 36.79% to 40%. Meat from Holli indigenous chicken showed the highest concentration of palmitic acid (22.81%) while the lowest content was recorded in meat from North indigenous chickens (19.84%; $P<0.05$). No significant difference was found between Palmitic acid content of meat from Holli, Fulani and Sahoue indigenous chickens ($P>0.05$). Meat from Fulani chicken exhibited considerably higher proportion of myristic acid than meat from Holli and North indigenous chickens ($P<0.05$). Others saturated fatty acids (lauric acid, margaric acid and arachidic acid) were found in low proportions (0.01 to 0.69%), but didn't vary significantly according to ecotypes ($P>0.05$).

Furthermore, monounsaturated fatty acid content was affected by the genetic type. Indeed, the highest monounsaturated fatty acid content was recorded in meat from Fulani indigenous chicken while the lowest content was found in Holli and North ecotypes ($P<0.05$). The middle values were observed in Sahoue and South ecotypes. C18: 1n-9, the predominant monounsaturated fatty acid found in chicken meats of all treatments, was more important in meat of Fulani and Sahoue ecotypes than in the others genetic types ($P<0.05$).

The proportion of polyunsaturated fatty acid depended on genotype and was higher in meat from North chicken (41.5%) than in others genetic types studied, while the lowest polyunsaturated fatty acid content was recorded in Fulani chickens (36.28%; $P<0.05$). Among the predominant polyunsaturated fatty acids, the highest content in linoleic acid (LA) was found in south chickens while the lowest was observed in Fulani and the middle values in Holli, North and Sahoue chickens ($P<0.05$). Moreover, arachidonic acid concentration was higher ($P<0.05$) in North chickens than in the others genetic types which showed similar contents in arachidonic acid.

The n-6 fatty acids content were largely more important than n-3 in chicken meats of all ecotypes with the highest n-6 fatty acids content (38.14%) found in North chickens and the lowest in Fulani (33.49%; $P<0.05$). Nevertheless, no significant difference was found in n-3 fatty acid contents (2.5% to 3.8%) among genetic type ($P>0.05$). However, the ratio n-6 to n-3 fatty acids was similar for the five genetic types and was between 11.85 and 16.52. Furthermore, the ratio PUFA to SFA varied significantly among genetic type ($P<0.05$) and was more important in North chicken meat (1.14) than in meat of the others 4 ecotypes. The lowest ratio (0.93) was recorded in Fulani and Sahoue chickens ($P<0.05$). However, any significant difference was found in ratio PUFA/SFA for meat from Holli, Fulani and Sahoue chickens ($P>0.05$). The middle PUFA/SFA ratio was observed in South chickens (1.03).

Variables (% of total fatty acids)	Holli	North	Fulani	Sahoue	South	RSD	ANOVA
C11:0 (Undecanoic acid)	0a	0.01a	0.02a	0a	0a	0.03	NS
C12:0 (Lauric acide)	0.17b	0.22b	0.69a	0.77a	0.4ab	0.73	NS
C14:0 (Myristic acid)	0.57b	0.54b	0.95a	0.92a	0.64ab	0.5	*
C16:0 (Palmitic acid)	22.81a	19.84b	21.79a	22.25a	21.72ab	2.4	*
C17:0 (Margaric acid)	0.12a	0.03b	0.12a	0.07ab	0.07ab	0.12	NS
C18:0 (Stearic acid)	16.26a	16.15a	15.5a	15.46a	15.61a	2.64a	NS
C20:0 (Arachidic acid)	0.03a	0.01a	0.07a	0.06a	0.03a	0.1	NS
Σ SFA	39.96a	36.79b	39.14a	39.54a	38.46ab	2.91	*
C14:1 (Myristoleic acid)	0a	0.03a	0.04a	0.02a	0.04a	0.06a	NS
C16:1(Palmitoleic acid)	1.04a	1.2a	1.33a	1.1a	1.3a	0.77	NS
C17:1 (Heptaecenoic acid)	0.022a	0.02a	0a	0.023a	0.03a	0.06	NS
C18:1 n9 (Oleic Acid)	19.62ab	18.51b	21.74a	21.51a	19.5ab	3.63	NS
C20:1 n9 (Gadoleic acid)	0.01ab	0.02ab	0.05b	0a	0.02ab	0.06	NS
C24:1 n9	1.01b	1.9a	1.42	1.2ab	1.1b	0.89b	NS
Σ MUFA	21.7b	21.67b	24.6a	23.9ab	21.98b	3.82	NS
C18:2 n-6 (LA)	19.4ab	18.3ab	17.1b	18.31ab	20a	3.38	NS
C18:3 n6	0.024a	0.015a	0.000a	0.000a	0.000a	0.42	NS
C18:3 n3 (ALA)	0.93a	0.015a	0.108a	0.142a	0.177a	1.8	NS
C20:2 n6 (Eicosadienoïc acid)	0.24a	0.233a	0.279a	0.246a	0.214a	0.2	NS
C20:3 n6 (Eicosatrienoïc acid)	0.72a	0.595a	0.660a	0.571a	0.633a	0.28	NS
C20:4 n6 (arachidonic acid)	14.2b	19a	15.492b	15.013b	16.078ab	4.52	NS
C20:5 n3 (EPA)	0.11b	0.341ac	0.276abc	0.184bc	0.367a	0.24	*
C22:6 n3 (DHA)	2.75ab	3.040a	2.406ab	2.146b	2.104ab	1.23	NS
Σ PUFA	38.3ab	41.5a	36.28b	36.61b	39.55ab	4.81	*
Σ n-3	3. 8a	3.39a	2.8a	2.5a	2.65a	2.42	NS
Σ n-6	34.55bc	38.14a	38.49b	34.14bc	36.91b	4.46	*
Σ n-6/Σ n-3	13.65 a	11.85a	13.26a	12.7a	16.52a	8.07	NS
PUFA/SFA	0.977b	1.138a	0.935b	0.935b	1.032ab	0.18	*

Table 1: Effect of genetic type on fatty acids profile of indigenous chicken meat of Benin. LA: Linoleic acid; DHA: Docosahexaenoïc acid; EPA: Eicosapentaenoïc acid; ALA: Alpha linolenic acid; NS: Non Significant; *: P<0.05. The means between the classes of the same line followed by different letters differ significantly with the threshold of 5%. RSD: Residual Standard Deviation; ANOVA: Analysis of Variance (test of significance).

Effect of breeding system on meat fatty acid composition

The fatty acid composition was significantly affected by the production system in the current study (Table 2). The major group of fatty acids in chicken meats of both breeding systems studied were palmitic and stearic (18:0) acids as Saturated Fatty Acids (SFA), oleic acid as monounsaturated fatty acid (MUFA), and Linoleic Acid (LA) and arachidonic acid as Polyunsaturated Fatty Acid (PUFA). Palmitic and oleic acids were the most abundant fatty acids in the various meats under analysis whatever the breeding system. Furthermore, the saturated fatty acid content (g/100 g) didn't vary significantly among production system (P>0.05) and fluctuated between 38.5% and 39.06%. However, lauric acid and myristic acids contents were significantly higher in meat from conventional breeding system than values recorded in chicken from traditional organic system (P<0.01).

Similarly, meat from improved breeding system was more rich in arachidic acid than the one from organic free range system (P<0.05). In return, stearic acid content was higher in chicken from organic free range system than the one bred under conventional breeding system (P<0.05).

Variables (% of total fatty acids)	Conventional breeding system	Organic breeding system	RSD	ANOVA
C11:0 (Undecanoic acid)	0.009a	0.003a	0.03	NS
C12:0 (Lauric acide)	0.2b	0.71a	0.73	**
C14:0 (Myristic acid)	0.53b	0.91a	0.5	**
C16:0 (Palmitic acid)	21.21a	22.16a	2.4	NS
C17:0 (Margaric acid)	0.08a	0.09a	0.12	NS
C18:0 (Stearic acid)	16.47a	15.13b	2.64a	*
C20:0 (Arachidic acid)	0.013b	0.064a	0.1	*
Σ SFA	38.5a	39.06a	2.91	NS
C14:1 (Myristoleic acid)	0.02a	0.04a	0.06a	NS
C16:1(Palmitoleic acid)	1.09a	1.3a	0.77	NS
C17:1 (Heptaecenoic acid)	0.02a	0.02a	0.06	NS
C18:1 n9 (Oleic Acid)	19.34b	21.01a	3.63	*
C20:1 n9 (Gadoleic acid)	0.007a	0.03a	0.06	NS
C24:1 n9	1.35a	1.3a	0.89b	NS
Σ MUFA	21.83b	23.69a	3.82	*
C18:2 n-6 (LA)	18.36a	18.85a	3.38	NS
C18:3 n6	0.009a	0.006a	0.42	NS
C18:3 n3 (ALA)	0.396a	0.151a	1.8	NS
C20:2 n6 (Eicosadienoïc acid)	0.25a	0.24a	0.2	NS
C20:3 n6 (Eicosatrienoïc acid)	0.62a	0.65a	0.28	NS
C20:4 n6 (arachidonic acid)	17.13a	14.77b	4.52	*
C20:5 n3 (EPA)	0.34a	0.18b	0.24	**
C22:6 n3 (DHA)	2.57a	2.41a	1.23	NS
Σ PUFA	39.67a	37.25b	4.81	*
Σ n-3	3.3a	2.73 a	2.42	NS
Σ n-6	36.37a	34.52a	4.46	NS
Σ n-6/Σ n-3	13.61a	13.59a	8.07	NS
PUFA/SFA	1.04a	0.96b	0.18	*

Table 2: Effect of breeding system on fatty acid composition of indigenous chicken meat of Benin. LA: Linoleic acid; DHA: Docosahexaenoïc acid; EPA: Eicosapentaenoïc acid; ALA: Alpha linolenic acid; NS: Non Significant ; *: P<0.05. The means between the classes of the same line followed by different letters differ significantly with the threshold of 5%. RSD: Residual Standard Deviation; ANOVA: Analysis of Variance (test of significance).

No significant difference was found between contents of undecanoic acid, palmitic acid, and margaric acid of meat from both breeding systems (P>0.05). Moreover, monounsaturated fatty acid content differed among breeding system (P<0.05). Indeed, the highest monounsaturated fatty acid content was recorded in meat from organic free range system (P<0.05). C18:1n-9 (predominant monounsaturated fatty acid) was abundant in chicken from organic free range system (P<0.05) than chicken from conventional breeding system. The others monounsaturated fatty acids found (myristoleic acid, palmitoleic acid, heptaecenoic acid, Gadoleic acid) showed similar contents (P>0.05).

The proportion of polyunsaturated fatty acid was higher in meat from conventional breeding system than in organic free range system (P<0.05). Arachidonic acid was abundant in meat from conventional breeding system than in organic breeding system (P<0.05). Similarly, the higher eicosapentaenoïc acid (EPA) content was found in chicken from conventional breeding system (P<0.05). Nevertheless, no significant difference was observed between the contents in Linoleic Acid (LA), C18:3n-6, alpha linolenic acid (ALA), Eicosadienoïc acid, Eicosatrienoïc acid and Docosahexaenoïc Acid (DHA) didn't differ significantly among breeding system (P>0.05).

Whatever the breeding system, the n-6 fatty acids content were largely more important than n-3 in chicken meat. The n-6 fatty acids content was on average of 36.37% in meat from conventional breeding system and was statistically similar to the concentration (34.5%) found in organic breeding system (P>0.05). However, n-3 PUFA content was of 3.3% in organic breeding system to 2.7% in conventional system (P<0.05). The ratio n-6 to n-3 fatty acids was not significantly different among both breeding systems (P>0.05), and was on average 13.6. However, the ratio PUFA/SFA was significantly higher in meat from conventional system than in meat from free range system (P<0.05).

Effect of type of muscle on meat fatty acid composition

The type of muscle affected considerably the fatty acid profile (Table 3). Concentration in lauric acid and palmitic acid were significantly higher in breast meat than thigh meat (P<0.05), while thigh meat was more rich in myristic acid and arachidic acid than breast (P<0.05). However, undecanoic acid, margaric acid and stearic acid contents of thigh and breast meats were similar. Likewise, the total saturated fatty acid content (g/100 g) didn't vary significantly according to the type of muscle (P>0.05) and was on average of 38.8%.

Furthermore, monounsaturated fatty acid content was significantly affected by type of muscle (P<0.001). Indeed, the higher total monounsaturated fatty acid content was recorded in thigh meat (P<0.001). C18:1 n-9 and palmitoleic acid was abundant in thigh meat than breast, whereas myristoleic acid and C24:1 n-9 were more concentrated in breast meat (P<0.05).

Variables (% of total fatty acids)	Breast meat	Thigh meat	RSD	ANOVA
C11:0 (Undecanoic acid)	0.012a	0a	0.03	NS
C12:0 (Lauric acide)	0.24b	0.66a	0.73	*

C14:0 (Myristic acid)	0.52b	0.93a	0.5	***
C16:0 (Palmitic acid)	22.4a	20.96b	2.4	*
C17:0 (Margaric acid)	0.1a	0.07a	0.12	NS
C18:0 (Stearic acid)	15.3a	16.29a	2.64a	NS
C20:0 (Arachidic acid)	0.01a	0.07b	0.1	*
Σ SFA	38.6a	38.97a	2.91	NS
C14:1 (Myristoleic acid)	0.04a	0.01b	0.06a	*
C16:1(Palmitoleic acid)	0.8a	1.59b	0.77	***
C17:1 (Heptaecenoic acid)	0.03a	0.01a	0.06	NS
C18:1 n9 (Oleic Acid)	18.3 a	22.1b	3.63	***
C20:1 n9 (Gadoleic acid)	0.02a	0.02a	0.06	NS
C24:1 n9	1.57a	1.08b	0.89b	*
Σ MUFA	20.76a	24.76b	3.82	***
C18:2 n-6 (LA)	16.96 a	20.26b	3.38	***
C18:3 n6	0.01a	0.01a	0.42	NS
C18:3 n3 (ALA)	0.08a	0.46a	1.8	NS
C20:2 n6 (Eicosadienoïc acid)	0.29a	0.19b	0.2	*
C20:3 n6 (Eicosatrienoïc acid)	0.83a	0.45b	0.28	***
C20:4 n6 (arachidonic acid)	18.97a	12.93b	4.52	***
C20:5 n3 (EPA)	0.39a	0.12b	0.24	***
C22:6 n3 (DHA)	3.12a	1.86b	1.23	***
Σ PUFA	40.6a	36.3b	4.81	***
Σ n-3	3.59a	2.43b	2.42	*
Σ n-6	37.05a	33.83b	4.46	**
Σ n-6/Σ n-3	10.09 a	17.1a	8.07	***
PUFA/SFA	1.07a	0.94b	0.18	**

Table 3: Effect of type of muscle on fatty acid composition of indigenous chicken meat of Benin. LA: Linoleic acid; DHA : Docosahexaenoïc acid; EPA: Eicosapentaenoïc acid; ALA: Alpha linolenic acid; NS: Non Significant ; *: P<0.05. The means between the classes of the same line followed by different letters differ significantly with the threshold of 5%. RSD: Residual Standard Deviation; ANOVA: Analysis of Variance (test of significance).

The proportion of polyunsaturated fatty acid was higher in thigh meat than breast (P<0.001). Arachidonic acid, docosahexaenoïc acid (DHA), eicosapentaenoïc acid (EPA) and Eicosatrienoïc acid were abundant in breast meat than thigh (P<0.001), while linoleic acid content of thigh meat was higher than in breast (P<0.001). Nevertheless, no significant difference was observed between the contents in C18:3 n-6 and alpha Linolenic Acid (ALA) of thigh and breast meat. The n-3 fatty acids and n-6 fatty acids contents of breast were largely higher than those of thigh meat (P<0.001). Therefore, the ratio n-6 to n-3 fatty acids in breast meat was highly lower than the ratio found in thigh meat (10 *vs* 17; P<0.001). However, the ratio PUFA/SFA was higher in breast than in thigh meat (P<0.01). Overall, the major group of fatty acids in chicken meats of breast and thigh meats were palmitic and stearic (18:0) acids as saturated fatty acids (SFA), oleic acid as Monounsaturated Fatty Acid (MUFA), and Linoleic Acid (LA) and arachidonic acid as Polyunsaturated Fatty Acid (PUFA). Palmitic and oleic acids were the most abundant fatty acids in the various meats under analysis whatever the type of muscle.

Interaction between ecotype and breeding mode on meat fatty acid composition

The interaction between ecotype and breeding mode was significantly observed on concentration in lauric acid, myristic acid, palmitic acid and stearic acid as Saturated Fatty Acids (SFA), oleic acid as Monounsaturated Fatty Acid (MUFA), and Linoleic Acid (LA) and eicosadienoïc acid as polyunsaturated fatty acid (P<0.05). Moreover, total saturated fatty acid content and total monounsaturated fatty acid content were significantly affected by interaction between ecotype and breeding mode. Indeed, in meat from Holli chicken, organic free range system provided meat more rich in saturated fatty acids and mostly palmitic acid (25.6% *vs* 20%) than conventional breeding system (P<0.05; Table 4). Similarly, Holli chickens from organic free range system showed higher content in monounsaturated fatty acid, especially oleic acid (21.55% *vs* 17.68%) and palmitoleic acid (1.63% *vs* 0.45%), while conventional breeding system favored highest content in polyunsaturated fatty acid (42.1% *vs* 34.6%) and above all arachidonic acid (16.9% *vs* 11.46%) than free range system (P<0.05).

In north chickens, no significant effect of interaction between ecotype and breeding mode was observed on the fatty acid profile (P>0.05). However, saturated fatty acids and monounsaturated fatty acids contents were numerically higher in north chickens from organic free range system than in North chickens from conventional breeding system. In return, North chickens from conventional breeding tend to have more polyunsaturated fatty than the one from free range system. Similarly, in South ecotype chickens, only the meat content in Myristoleic acid varied according to the breeding system with the highest content found in chicken from free range system (P<0.05).

Furthermore, Fulani chickens from conventional breeding was more rich in undecanoic acid and margaric acid (P<0.05), whereas birds from free range system showed the highest contents in arachidic acid and gadoleic acid (P<0.05).

Sahoue chickens bred under organic free range system provided meat more rich in lauric acid, myristic acid, arachidic acid and oleic acid than meat from birds of the same genetic type bred under conventional breeding system. In return, Sahoue chickens from conventional breeding system showed the highest content in stearic acid and linoleic acid (P<0.05). The interaction between ecotype and breeding system on fatty acid composition of indigenous chicken meat of Benin is given in Table 4.

Variables (% of total fatty acids)	Holli		North		Fulani		Sahoue		South		RSD	Ecotype x
	Conventional	Organic	Conventional	Organic	Conventional	Organic	Conventional	Organic	Conventional	Organic		Breeding system
C11:0 (Undecanoic acid)	0a	0a	0a	0.02a	0.04a	0b	0a	0a	0a	0a	0.03	NS
C12:0 (Lauric acide)	0.17a	0.17a	0.27a	0.17a	0.24a	1.14a	0.09a	1.45b	0.2a	0.59a	0.73	*
C14:0 (Myristic acid)	0.43a	0.71a	0.59a	0.49a	0.63a	1.27a	0.477a	1.36b	0.53a	0.75a	0.5	*
C16:0 (Palmitic acid)	20.06a	25.56b	19.14a	20.55a	22.44a	21.2a	22.15a	22.35a	22.24a	21.2a	2.4	**
C17:0 (Margaric acid)	0.12a	0.12a	0a	0.06a	0.18a	0.06b	0.03a	0.12a	0.06a	0.08a	0.12	NS
C18:0 (Stearic acid)	17.58a	14.94b	15.59a	16.71a	16.19a	14.82a	17.68a	13.26b	15.31a	15.9a	2.64	*
C20:0 (Arachidic acid)	0.06a	0a	0a	0.02a	0.001a	0.13b	0a	0.11b	0a	0.06a	0.1	*
Σ SFA	38.43a	41.5b	35.5a	38a	39.72a	38.57a	40.42a	38.65a	38.35a	38.6	2.91	NS
C14:1 (Myristoleic acid)	0a	0a	0.04a	0.03a	0.05a	0.031a	0a	0.046a	0a	0.1b	0.06	NS
C16:1(Palmitoleic acid)	0.45a	1.63b	1.33a	1.06a	1.4a	1.25a	0.91a	1.28a	1.35a	1.25a	0.77	NS
C17:1 (Heptaecenoic acid)	0.043a	0a	0.041a	0a	0.002a	0a	0a	0.046a	0a	0.06	0.06	NS
C18:1 n9 (Oleic Acid)	17.68a	21.55b	20.21a	16.81a	20.22a	23.27a	19.58a	23.44b	19.01a	19.98a	3.63	*
C20:1 n9 (Gadoleic acid)	0.02a	0a	0a	0.03a	0.01a	0.09b	0a	0a	0a	0.04a	0.06	NS
C24:1 n9	1.28a	0.74a	1.77a	2.02a	1.67a	1.17a	1.1a	1.29a	0.92a	1.26a	0.89	NS
Σ MUFA	19.48a	23.92b	23.4a	19.94a	23.36a	25.81a	21.6a	26.11b	21.29a	22.68a	3.82	*
C18:2 n-6 (LA)	19.58a	19.2a	17.02a	19.58a	15.88a	18.23a	19.85a	16.77b	19.48a	20.49a	3.38	NS
C18:3 n6	0.05a	0b	0a	0.030a	0.001a	0a	0a	0a	0a	0a	0.42	NS
C18:3 n3 (ALA)	1.734a	0.116a	0a	0.030a	0.059a	0.156a	0.044a	0.240a	0.141a	0.213a	1.8	NS
C20:2 n6 (Eicosadienoïc acid)	0.3a	0.18a	0.28a	0.19a	0.36a	0.2a	0.21a	0.28a	0.09a	0.34b	0.2	*
C20:3 n6 (Eicosatrienoïc acid)	0.59a	0.85a	0.558a	0.631a	0.785a	0.534a	0.521a	0.622a	0.658a	0.61a	0.28	NS
C20:4 n6 (arachidonic acid)	16.9a	11.46b	19.15a	19.8a	16.5a	14.5a	15.4a	14.64a	17.7a	14.49a	4.52	NS
C20:5 n3 (EPA)	0.22a	0a	0.43a	0.253a	0.388a	0.164a	0.190a	0.178a	0.445a	0.29a	0.24	NS
C22:6 n3 (DHA)	2.72a	2.78a	3.57a	2.51a	2.91a	1.88a	1.77a	2.5a	1.89a	2.32a	1.23	NS
Σ PUFA	42.09a	34.59b	41.01a	42.06a	36.93a	35.63a	37.98a	35.25a	40.37a	38.74a	4.81	NS
Σ n-3	4.68a	2.89 a	4a	2.8a	3.36a	2.21a	2a	2.94a	2.47a	2.82a	2.42	NS
Σ n-6	37.41a	31.69b	37a	39.26a	33.56a	33.41b	35.97a	32.3a	37.89a	35.92a	4.46	NS
Σ n-6/Σ n-3	15.71a	11.57a	10.04a	13.66a	9.94a	16.59a	12.67a	12.74a	19.66a	13.39a	8.07	NS

PUFA/SSFA	1.101a	0.854b	1.160a	1.116a	0.942a	0.928a	0.959a	0.911a	1.060a	1.003a	0.18	NS

Table 4: Interaction between ecotype and breeding system on fatty acid composition of indigenous chicken meat of Benin. LA: Linoleic acid; DHA: Docosahexaenoïc acid; EPA: Eicosapentaenoïc acid; ALA: Alpha linolenic acid; NS: Non Significant ; *: P<0.05. The means between the classes of the same line followed by different letters differ significantly with the threshold of 5%. RSD: Residual Standard Deviation; ANOVA: Analysis of Variance (test of significance).

Interaction between ecotype and muscle on fatty acid composition of meat

The interaction between ecotype and muscle is shown in Table 5. In group of saturated fatty acids, the interaction between ecotype and muscle had affected the concentrations of myristic acid, margaric acid and stearic acid (P<0.05). The highest contents of these saturated fatty acids were found in thigh meat of all the ecotypes where this interaction was observed (P<0.05).

Concerning monounsaturated fatty acids, only myristoleic acid concentration was affected by the interaction between ecotype and muscle with the highest content observed in breast meat (P<0.05).

As for polyunsaturated fatty acids, the interaction between ecotype and muscle had affected linoleic acid and eicosapentaenoïc acid contents (P<0.05). Linoleic acid, one of the predominant polyunsaturated fatty acids, was more abundant in thigh meat of all genetic types investigated than in breast meat (P<0.05). However, n-3 polyunsaturated fatty acids and n-6 polyunsaturated fatty acids contents of meat weren't affected by the interaction between ecotype and muscle (P>0.05), but were more important in breast than in thigh whatever the genetic type. Similarly, the ratio n-6 to n-3 fatty acids was high in thigh and breast meat of all ecotypes of chicken studied, but wasn't influenced by the interaction between ecotype and muscle (P>0.05). Furthermore, the ratio PUFA/SFA wasn't affected by the interaction between ecotype and muscle (P>0.05).

Variables (% of total fatty acids)	Holli		North		Fulani		Sahoue		South		RSD	Ecotype x
	Breast	Thigh	Breast	Thigh	Breast	Thigh	Breast	Thigh	Breast	Thigh		Muscle
C11:0 (Undecanoic acid)	0a	0a	0.01a	0a	0.04a	0b	0a	0a	0a	0a	0.03	NS
C12:0 (Lauric acide)	0.23a	0.1a	0.16a	0.28a	0.41a	0.97a	0.21a	1.34b	0.2a	0.6a	0.73	NS
C14:0 (Myristic acid)	0,67a	0,47a	0,41a	0,67a	0,65a	1,25b	0,48a	1,36b	0,39a	0,89a	0.5	*
C16:0 (Palmitic acid)	24,11a	21,51b	19,47a	20,22a	23,10a	20,49a	22,69a	21,81a	22,67a	20,77a	2.4	NS
C17:0 (Margaric acid)	0,06a	0,18b	0,06a	0,00a	0,15a	0,09a	0,08a	0,06a	0,14a	0b	0.12	*
C18:0 (Stearic acid)	14,14a	18,39b	16,14a	16,16a	14,87a	16,14a	15,98a	14,96a	15,38a	15,83a	2.64	*
C20:0 (Arachidic acid)	0,00a	0,06a	0,02a	0,00a	0,01a	0,14b	0,00a	0,11b	0,04a	0,02a	0.1	NS
Σ SFA	39,22a	40,71a	36,28a	37,31a	39,22a	39,07a	39,44a	39,64a	38,83a	38,10a	2.91	NS
C14:1 (Myristoleic acid)	0,00a	0,00a	0,07a	0b	0,07a	0,01a	0,00a	0,04a	0,07a	0,01b	0.06	*
C16:1(Palmitoleic acid)	0,82a	1,26a	0,43a	1,97b	1,25a	1,41a	0,61a	1,59b	0,90a	1,71a	0.77	NS
C17:1 (Heptaecenoic acid)	0,05a	0,00a	0,04a	0,00a	0,00a	0,00a	0,00a	0,04a	0,05a	0,01a	0.06	NS
C18:1 n9 (Oleic Acid)	19,59a	19,64a	15,83a	21,19b	19,79a	23,7b	18,24a	24,79b	18,04a	20,95a	3.63	NS
C20:1 n9 (Gadoleic acid)	0a	0.02a	0.03a	0a	0.04a	0.05a	0a	0a	0.04a	0a	0.06	NS
C24:1 n9	1a	1.01a	2.01a	1.78a	2.1a	0.75b	1.58a	0.81b	1.13a	1.05a	0.89	NS
Σ MUFA	21.46a	21.94a	18.41a	24.93b	23.24a	25.92a	20.43a	27.28b	20.24a	23.72a	3.82	NS
C18:2 n-6 (LA)	16.28a	22.49b	16.51a	20.1a	14.03a	20.09b	18.03a	18.58a	19.96a	20.01a	3.38	*
C18:3 n6	0a	0.1b	0.03a	0a	0a	0a	0a	0a	0a	0a	0.42	NS
C18:3 n3 (ALA)	0.06a	1.8a	0.01a	0.02a	0.06a	0.16a	0.09a	0.2a	0.2a	0.15a	1.8	NS
C20:2 n6 (Eicosadienoïc acid)	0.24a	0.24a	0.26a	0.2a	0.32a	0.23a	0.31a	0.19a	0.3a	0.12a	0.2	NS

C20:3 n6 (Eicosatrienoïc acid)	0.86a	0.57b	0.81a	0.38b	0.88a	0.44b	0.77a	0.37b	0.8a	0.5b	0.28	NS
C20:4 n6 (arachidonic acid)	18.37a	9.99b	23.63a	14.34b	18.49a	12.49b	17.82a	12.2b	16.54a	15.61a	4.52	NS
C20:5 n3 (EPA)	0.1a	0.14a	0.5a	0.2b	0.42a	0.14b	0.34a	0.03b	0.64a	0.1b	0.24	*
C22:6 n3 (DHA)	3.42a	2.07b	3.55a	2.52a	3.35a	1.5b	2.77a	1.51b	2.5a	1.72a	1.23	NS
Σ PUFA	39.32a	37.35a	45.3a	37.75b	37.54a	35.02a	40.14a	33.08b	40.93a	38.17a	4.81	NS
Σ n-3	3.57a	3.99 a	4.05a	2.73 a	3.81a	1.76 a	3.2a	1.73 a	3.33a	1.96a	4.99	NS
Σ n-6	35.75a	33.35a	41.25a	35.01b	33.72a	33.25b	36.93a	31.34b	37.6a	36.21b	0.41	NS
Σ n-6/Σ n-3	10.26a	17.02a	9.38a	14.32a	9.25a	17.27a	10.36a	15.04a	11.2a	21.84b	7.95	NS
PUFA/SSFA	1.014a	0.94a	1.26a	1.01b	0.96a	0.9a	1.03a	0.84b	1.05a	1.01a	0.18	NS
LA: Linoleic acid; DHA: Docosahexaenoïc acid; EPA: Eicosapentaenoïc acid; ALA: Alpha linolenic acid; NS: Non Significant; *: P<0.05. The means between the classes of the same line followed by different letters differ significantly with the threshold of 5%. RSD: Residual Standard Deviation; ANOVA: Analysis of Variance (test of significance).												

Table 5: Interaction between ecotype and type of muscle on fatty acid composition of indigenous chicken meat of Benin

Interaction between breeding mode and muscle on fatty acid composition of meat

The interaction between breeding mode and muscle was significantly observed on concentration in lauric acid, myristic acid, margaric acid and stearic acid as saturated fatty acids (SFA), oleic acid as monounsaturated fatty acid (MUFA), and linoleic acid (LA) and eicosadienoïc acid as polyunsaturated fatty acid (P<0.05). Moreover, total contents in monounsaturated fatty acids and polyunsaturated fatty acids was significantly affected by interaction between ecotype and breeding mode (P<0.05).

Indeed, in traditional free range system, thigh provided meat more rich in margaric acid and polyunsaturated fatty acids than breast meat (P<0.05), while breast meat showed the higher content in lauric acid, myristic acid, oleic acid and linoleic acid compared to thigh meat (P<0.05). In Conventional breeding system, thigh meat was more rich in palmitic acid than breast meat (P<0.05; Table 6), whereas breast meat had recorded the highest content in stearic acid and linoleic acid (P<0.05).

However, n-3 polyunsaturated fatty acids and n-6 polyunsaturated fatty acids contents of breast weren't affected by this interaction. Similarly, the ratio n-6 to n-3 fatty acids and the ratio PUFA/SFA weren't influenced by the interaction between breeding mode and muscle (P>0.05). The interaction between breeding system and type of muscle on the fatty acid composition is presented in Table 6.

	Conventional breeding system		**Organic breeding system**		**RSD**	**Breeding mode x Muscle**
Variables (% of total fatty acids)	**Thigh**	**Breast**	**Thigh**	**Breast**		
C11:0 (Undecanoic acid)	0.02a	0a	0.01a	0a	0.03	NS
C12:0 (Lauric acide)	0.21a	0.17a	0.27a	1.14b	0.73	**
C14:0 (Myristic acid)	0.47a	0.6a	0.59a	1.26b	0.5	*
C16:0 (Palmitic acid)	22.23a	20.18b	22.59a	21.73a	2.4	NS
C17:0 (Margaric acid)	0.06a	0.09a	0.13a	0.04a	0.12	*
C18:0 (Stearic acid)	15.3a	17.65b	15.31a	14.94a	2.64	*
C20:0 (Arachidic acid)	0.002a	0.023a	0.019a	0.109b	0.1	NS
Σ SFA	38.3a	38.7a	38.9a	39.22a	2.91	NS
C14:1 (Myristoleic acid)	0.036a	0.003a	0.053a	0.022a	0.06	NS
C16:1(Palmitoleic acid)	0.78a	1.4b	0.82a	1.771b	0.77	NS
C17:1 (Heptaecenoic acid)	0.04a	0a	0.02a	0.021a	0.06	NS

C18:1 n9 (Oleic Acid)	18.65a	20.02a	17.94a	24.08b	3.63	**
C20:1 n9 (Gadoleic acid)	0.001a	0.013a	0.05a	0.02a	0.06	NS
C24:1 n9	1.61a	1.1a	1.53a	1.1a	0.89	NS
Σ MUFA	21.12a	22.54a	20.4a	26.98b40.435ionnel	3.82	**
C18:2 n-6 (LA)	15.81a	20.91b	18.11a	19.6a	3.38	*
C18:3 n6	0a	0.02a	0.012a	0a	0.42	NS
C18:3 n3 (ALA)	0.037a	0.754a	0.128a	0.174a	1.8	NS
C20:2 n6 (Eicosadienoïc acid)	0.24a	0.25a	0.33a	0.15b	0.2	*
C20:3 n6 (Eicosatrienoïc acid)	0.82a	0.43b	0.83a	0.47b	0.28	NS
C20:4 n6 (arachidonic acid)	20a	14.3b	17.95a	11.6b	4.52	NS
C20:5 n3 (EPA)	0.46a	0.21b	0.33a	0.02b	0.24	NS
C22:6 n3 (DHA)	3.22a	1.92b	3.02a	1.8b	1.23	NS
Σ PUFA	40.6a	38.75a	40.7a	33.8b	4.81	*
Σ n-3	3.71a	2.88 a	3.47a	2:00 AM	4.99	NS
Σ n-6	36.88a	35.86 a	37.22a	31.81b	0.41	*
Σ n-6/Σ n-3	9.58a	17.62b	10.62a	16.58b	7.95	NS
PUFA/SSFA	1.08a	1.01a	1.05a	0.87b	0.18	NS

Table 6: Interaction between breeding system and type of muscle on fatty acid composition of indigenous chicken meat of Benin. LA: Linoleic acid; DHA: Docosahexaenoïc acid; EPA: Eicosapentaenoïc acid; ALA: Alpha linolenic acid; NS: Non Significant; *: P<0.05. The means between the classes of the same line followed by different letters differ significantly with the threshold of 5%. RSD: Residual Standard Deviation; ANOVA: Analysis of Variance (test of significance).

Discussion

Effect of ecotype on fatty acid composition of meat

In the current study, the fatty acid composition of chicken revealed varying responses in the different genetic type investigated. This observation confirm the results of Dal Bosco et al. [12] and Boschetti et al. [13] who reported considerable effect of genotype on fatty acid profile when they were studying the fatty acid composition of meat and estimated indices of lipid metabolism in Ancona, Leghorn, crossbreed Cornish × Leghorn, Kabir, Naked neck and Ross chickens reared under organic system. Similarly, Sirri et al. [23], comparing the lipid composition of different chicken strains (fast-growing Cobb 700 strain, medium-growing NN strain, and the slow-growing Brown Classic Lohman strain) reared under organic conditions, observed not only an increase in the lipid content of the fast-growing strain but also some great variations for the main fatty acids. Significant effect of genotype on fatty acid composition was also reported by Mathlouthi et al. [24] among meat from Sasso T88, T44NI and T77N reared with outdoor access and slaughtered at 47 days old.

The predominant fatty acids in chicken meats of all treatments in the present study were palmitic and stearic acids as saturated fatty acid (SFA), oleic acid as monounsaturated fatty acid (MUFA), linoleic acid (LA) and arachidonic acid as polyunsaturated fatty acid (PUFA). These results confirm the finding of De Marchi et al. [25] in meat of Padovana breed of native chicken of Veneto region in Italy. This finding was also consistent with that reported by Pereira et al. [26] on fatty acid composition of chicken fat and Sheu & Chen [27] on edible broiler skin fat. Similar results were also reported from several studies such as the one of Kralik et al. [28] on fatty acids composition of Ross 208 chicken meat produced in indoor and outdoor rearing systems, and Ponte et al. [29] when studying the effect of pasture intake on the performance and meat sensory attribute of free range broilers. These authors also found that palmitic and oleic acids were the most abundant fatty acids in the various meats under analysis. The same observation was made in the current study. The saturated fatty acid (SFA) content differed significantly among genotype in our study and was on average of 38.5%. This average concentration in SFA is higher than those of 35.15% reported by De Marchi et al. [25] in meat fat of Padovana breed of chicken of Italy and by Castellini et al. [30] for Ross 205 and Kabir chickens reared in organic rearing system. This variation of SFA content among genetic type was also reported by Dal Bosco et al. [12], where the higher value was observed in Leghorn and the lower value in commercial lines. Additionally, they showed that Leghorn and Ancona chickens exhibited higher amounts of stearic acid (C18:0) than crossbreed Cornish × Leghorn, Kabir, Naked neck and Ross chickens reared under the same organic system. The Highest saturated fatty acids contents recorded in Holli breed (39.96%) in the current study remains lower than those reported for Thai local chickens (62%) by Wattanachant et al. [31].

The total MUFA concentrations, which in chickens are related either to the endogenous synthesis or to the gut absorption from the diet [12], showed the highest levels in Fulani ecotype in our study, and were mainly represented by oleic acid. This result is consistent with the reports of Zanetti et al. [11] on the fatty acid profile of three Italian local chicken breeds, and Sirri et al. [23] in meat of fast, medium and slow growing chickens. The observed differences in SFA and MUFA among the studied ecotypes can be attributable only to the genetic determinism, since diets and rearing system were completely similar for all breeds during the whole experimental period.

The proportion of polyunsaturated fatty acid was higher in meat from north chicken (41.5%) than in others genetic types studied, while the lowest polyunsaturated fatty acid content was recorded in Fulani chickens (36.28%). Our finding is consistent with PUFA concentration of about 40% reported by Zanetti et al. [11] on raw breast (without skin) fatty acid composition of three Italian local chicken breeds (Padovana, Ermellinata and Pépoi) reared in extensive systems until 190 days of age, but higher than PUFA contents recorded by Kralik et al. [28] on fatty acids composition of Ross 208 chicken meat produced in indoor and outdoor rearing systems, and Küçükyilmaz et al. [16] in conventional fast growing chickens (31.4%) and conventional slow growing chickens (32.2%). Ponte et al. [29] found in free range broiler that polyunsaturated fatty acid content fluctuated between 29.6% and 31.3%. These PUFA contents are also lower than those recorded in our study. Franco et al. [32] found when studying carcass morphology and meat quality from roosters slaughtered at eight months that unsaturated fatty acids constituted the main contribution to total amount of fatty acid, where monounsaturated oleic acid was the major compound, and found higher concentrations in commercial breed. These authors also showed that Mos breed showed higher amounts of polyunsaturated fatty acids and lower amounts of monounsaturated fatty acids than Sasso T-44.

The n-6 PUFA contents in our study were largely more important than those of n-3 PUFA in chicken meats of all ecotypes. Our finding is consistent with the results of Kralik et al. [28], Zanetti et al. [11] on raw breast (without skin) fatty acid composition of three Italian local chicken breeds, Straková et al. [17], Dal Bosco et al. [12] in meat fat of Ancona, Leghorn, crossbreed Cornish × Leghorn, Kabir, Naked neck and Ross chickens reared under organic system, but contrary to the reports of De Marchi et al. [25] in meat fat of Padovana breed of chicken reared in an organic production system.

The concentrations in n-6 PUFA found in indigenous chicken meat in the current study varying from 33% to 38% were greater than those reported for Thai indigenous chicken or commercial broilers which were respectively about 4% and 8.65% [31]. De Marchi et al. [25] found n-6 PUFA content of about 28% in Padovana chicken breed of Italy reared in an organic production system, while Mathlouthi et al. [24] reported the n-6 PUFA concentrations of 23.5 g/100 g, 22.48 g/100 g and 20.55 g/100 g of raw breast muscle respectively in Sasso T88, T44NI, and T77N broiler strains. The levels in n-6 PUFA found in indigenous chicken meat in the present study were consistent with the value of 34% of total fatty acid found by Ponte et al. [29] in free range broiler, and 33.53-35% recorded by Taulescu et al. [18] in conventional broiler breast meat.

The concentrations in n-3 PUFA found in indigenous chicken meat herein were higher than those reported by Ponte et al. [29] in free range broiler (2.47%-2.96% of FA) and Taulescu et al. [18] respectively in breast meat of conventional broiler. Furthermore, the n-3 PUFA contents obtained herein were largely higher than those of 0.61% and 0.68% of total FA reported respectively in conventional and organic slow growing broilers (Hubbard Red-JA) by Küçükyilmaz et al. [16], but consistent with the finding of Straková et al. [17] in chicken feed with lupin containing diet.

Therefore, the ratio n-6 PUFA to n-3 PUFA fatty acids obtained herein (11.85-16.52) was higher than 4:1, recommended as favorable for human health [33], but 4-fold lower than the ratio n-6 PUFA to n-3 PUFA found in thigh (39.2-50.7) and breast meat (46.7-50.9) of slow-growing Hubbard Red-JA by Küçükyilmaz et al. [16] in conventional and organic breeding systems, and 2-3 fold lower than those reported in conventional fast-growing Ross 308 broiler by Küçükyilmaz et al. [16] and Jahan et al. [34] and Taulescu et al. [18] in breast meat of conventional broiler. However, the ratios found herein were consistent with those reported by Ponte et al. [29] in free range broiler (11.5-11.7) and Dal Bosco et al. [12] in meat fat of Ancona, Leghorn, crossbreed Cornish × Leghorn, Kabir, Naked neck and Ross chickens reared under organic system. Obtained ratios of PUFA n-6 / PUFA n-3 in chickens of the five genetic types studied in the current study are slightly higher than research results of Komprda et al. [35], Kralik et al. [36] and Zanetti et al. [11]. A high ratio is thought to promote the pathogenesis of many diseases because n-6 metabolites are considered to be pro-thrombotic and pro-inflammatory [37,38].

Furthermore, the ratio PUFA to SFA in the present study also varied significantly among genetic type. The lowest ratio was about 0.93 and the highest ratio was of 1.13. These ratios are higher than recommended value (0.46) for human health [38]. Our ratios PUFA/SFA are consistent with the finding of Dal Bosco et al. [12] for the Padovana chicken, lower than those of 1.34 reported by Küçükyilmaz et al. [16] in slow growing broilers (Hubbard Red-JA), 1.88 and 2.63 found by Taulescu et al. [18] respectively in breast and thigh meat of broiler. Nevertheless, these values are higher than those reported by Cortinas et al. [39] in broilers fed with diets supplemented with 15 g of PUFA/kg of feed, and Franco et al. [32] who found that the relation PUFA/SFA was above 0.68 in Mos breed and slightly lower for roosters from hybrid line Sasso T44.

Effect of breeding mode on fatty acid composition of meat

The saturated fatty acid content (g/100 g) didn't vary significantly among production system and fluctuated between 38.5% and 39.06%. This finding is consistent with the results of Kralik et al. [28] on fatty acids composition of Ross 208 chicken meat produced in indoor and outdoor rearing systems. No effect of production system on total saturated fatty acid content was also reported by Molee et al. [40] in Thai indigenous chicken meat produced under conventional or organic rearing system. These observations are in contrast with results found by Castellini et al. [30] and Husak et al. [41] that showed that free-range broilers had more SFA and less MUFA compared to conventional birds. However, saturated fatty acid as lauric acid, myristic acid and arachidic acid contents were significantly higher in meat from organic free range system than values recorded in chicken from conventional breeding system in the current study. This difference could be due to the fact that chicken in free range fed kitchen residues [20] from household and restaurant where ground nut oil or palm nut oil are generally used during cooking. The variation of these saturated fatty acids among production system was also reported by Kralik et al. [28]. In return, stearic acid content was of 16.5% in chicken from conventional breeding system *vs* 15.1% in chicken bred under organic free range system in the current study. These stearic acid contents recorded in our study in both rearing system are higher than the values

of 10.4% and 12.9% reported respectively from indoor and outdoor chicken meat by Kralik et al. [28].

Moreover, the highest monounsaturated fatty acid content was recorded in meat from organic free range system in the current work. C18:1n-9, the predominant monounsaturated fatty acid in our study, was abundant in chicken from organic free range system than chicken from conventional breeding system. This finding is consistent with the results of Ponte et al. [29] who found that C18:1n-9 was the major group of monounsaturated fatty acid in chickens bred under European free range system or conventional intensive system with the highest C18:1n-9 content recorded in meat from free range system. Although the proportion of 18:1n-9 was increased in meat from birds from free range system, the level of the ALA in meat didn't vary significantly among breeding systems and remained very weak. This observation could be explained by the higher conversion of this fatty acid (ALA) to its long-chain derivatives. Linoleïc acid is reported to be competitor of ALA in the metabolism of the 2 essential fatty acid families [29,12].

Several studies reported higher polyunsaturated fatty acid (PUFA), n-3 PUFA and n-6 PUFA concentration when chickens were reared under organic and free range system [34,41-43]. Moreover, Martino et al. [43] and Bostami et al. [14] pointed out a correlation between the PUFA content of feed and meat. These reports are contrary to our finding who indicated slightly lower polyunsaturated fatty acid (PUFA) and n-3 PUFA content in meat from chickens reared under free range system. One of the reasons for these discrepancies among investigations was attributed to the green grass consumption of broilers in organic systems [41,42]. In our study, this relatively lower polyunsaturated fatty acid (PUFA) and n-3 PUFA content in meat from chickens reared under free range system could be due to the fact that our chicks were born during the rainy season (on September), reared under conventional breeding system in confinement until 3 months old before being rejected in free range from November to the end of February and then slaughtered for the study. This period of free range rearing coincided with the great dry season in our country where grass and leguminous are less available, and therefore, the levels of pasture intake (in terms of DM) in birds with access to the legume-based pastures were low and replaced mainly by kitchen residues found during scavenging. Now, plant species, specially legumes and grass have a higher amount of ALA as reported by Dewhurst et al. [44], Van Ranst et al. [45], and Wyss & Collomb [46]. Our results are consistent with the finding of Ponte et al. [29], who reported that the fatty acid composition of meat from free-range broilers was modified only slightly by grass consumption, with the higher polyunsaturated fatty acid (PUFA) and n-3 PUFA concentration found in conventional boiler than free range. Although pasture intake was available for the birds in the organic system in their study between the ages of 21 and 81 days, the thigh meat of the organically reared birds was markedly lower in omega-3 content when compared with birds kept indoors. The report by Jahan et al. [34] that demonstrated that organic breast meat had significantly lower contents of n-3 fatty acids is in full agreement with the present findings. Also, a recent study showed that free-range meat contained lower quantities of most n-3 fatty acids (C18:3, C18:4, EPA) and had a consistently higher n-6/n-3 ratio than that from intensively reared birds [47]. It has been suggested that broiler chicks in an organic system are usually exposed to more and different environmental factors compared with the conventional indoor systems; hence, they might have utilized omega-3 as an essential nutrient to support their immune system against external stimulations, rather than deposit it in the meat. The indication by Cook et al. [48] that omega-3 stimulates the body's physiological process during stress appears to confirm our corresponding approach.

Moreover, It was reported that the incorporation of vegetable oils [49] or oily fish by-products [50,51] can readily improve the content of poultry meat in n-3 fatty acids, particularly in α-linolenic acid (ALA; 18:3n-3), by increasing the levels of n-3 PUFA in poultry diets. This report also explain the slightly higher n-3 fatty acids content found in chicken bred under conventional breeding system because their feed contain soybean cake and whole fish meal.

Furthermore, the higher eicosapentaenoïc acid (EPA) content was found in chicken from conventional breeding system in the present study. This difference may result from the fish meal used in feed composition for chickens reared under conventional breeding system, since fish oil is one of dietary source of EPA as reported by Alireza Syadati et al. [52].

Whatever the breeding system, the n-6 fatty acids content were largely more important than n-3 in chicken meat in the current study. Moreover, n-6 fatty acids concentrations were greater in confinement conventional breeding system than in organic free range system. Our results confirm those of Molee et al. [40] in Thai indigenous chicken meat reared under conventional and free range systems, Dal Bosco et al. [12] in organic Padovana chicken breed, Ponte et al. [29] in free range broiler, Küçükyilmaz et al. [16] in conventional and organic slow growing broilers (Hubbard Red-JA) and Straková et al. [17] in chicken feed with lupin containing diet.

The n-3 PUFA contents obtained herein in confinement system or organic free range system were largely higher than those of 0.61% and 0.68% of total FA reported respectively in conventional and organic slow growing broilers (Hubbard Red-JA) by Küçükyilmaz et al. [16], but consistent with the finding of Straková et al. [17] in chicken feed with lupin containing diet. According to Rymer & Givens [53], n-3 fatty acids are some vital components in the retina and the membrane phospholipids of the brain, which reduce the risk of coronary heart disease. However, the ratio PUFA/SFA was higher in chicken from conventional breeding system than in meat from organic breeding system. Therefore, indigenous chicken meat of Benin reared under free range system is more useful for human health, since the recommended value for human health is 0.46 [38]. As changing the fat content and fatty acids profile of feeds can be an effective way to improve the consumer's health [54], indigenous chicken meat of Benin can be a major source of dietary fat.

Effect of type of muscle on fatty acid composition of meat

The type of muscle affected considerably the fatty acid profile. Concentration in lauric acid and palmitic acid were significantly higher in breast meat than thigh meat, while thigh meat was richer in myristic acid and arachidic acid than breast. The variation of these saturated fatty acids among type of muscle was also reported by Kralik et al. [28] with the highest content in lauric acid and palmitic acid and the lowest myristic acid content recorded in breast meat as found in the current study. Similarly, Taulescu et al. [18] reported that breast was richer in palmitic acid than thigh meat of broiler.

Furthermore, the higher total monounsaturated fatty acid content was recorded in thigh meat. C18:1n-9 and palmitoleic acid was abundant in thigh meat than breast, whereas myristoleic acid and C24:1 n-9 was more concentrated in breast meat. This result is consistent with the finding of Straková et al. [17] in thigh and breast meat of Ross 308 boiler, Taulescu et al. [18] in broiler, and

Küçükyilmaz et al. [16] in thigh and breast meat of conventional and organic slow growing broilers (Hubbard Red-JA).

In the current study, the proportion of polyunsaturated fatty acid was higher in thigh meat than breast. C20:3 n-3, docosahexaenoïc acid (DHA), eicosapentaenoïc acid (EPA) and Eicosatrienoïc acid was abundant in breast meat than thigh, while conjugated linoleic acid content of thigh meat was higher than in breast. Our finding confirm those reported by Straková et al. [17] and Küçükyilmaz et al. [16], but contrary to the one found by Taulescu et al. [18] who pointed out that polyunsaturated fatty acid was predominant in breast than thigh. This difference among investigation may be due to the fact that Taulescu et al. [18] had supplemented the diet of their birds with omega-3 rich elements (flax seed).

Regarding the distribution of omega-3 in the two tissues it can be observed that pectoral muscles muscle present significantly higher value than thigh. Kralik et al. [28] and Straková et al. [17] had observed similar results. In contrast, Zuidhof et al. [55], Taulescu et al. [18] and Küçükyilmaz et al. [16] observed that thigh muscle presents significantly higher value of omega-3 content than breast.

However, the ratio PUFA/SFA was higher in breast than in thigh meat. Examined ratio of PUFA n-6/PUFA n-3 in the lipids of thigh and breast muscles of chickens was lower than those reported in several studies [16,34,18] and therefore can be acceptable for human health [33].

Conclusion

Overall, the current study carried out on the fatty acids composition of meat of local poultry population of *Gallus gallus* species of Benin reared under free range and conventional breeding systems is the first one on the characterization of these local poultry populations. Overall, palmitic and oleic acids were the most abundant fatty acids in the various meats under analysis. The highest SFA, MUFA and PUFA concentrations were found respectively in Holli, Fulani and North ecotypes. Fulani and Sahoue chickens showed the lowest ratios PUFA/SFA. Chicken from organic free range system were richer in lauric acid, myristic acid and arachidic acid than chicken from conventional breeding system. The highest monounsaturated fatty acid content and lowest polyunsaturated fatty acid content were also recorded in meat from organic free range system. The predominant eicosapentaenoïc acid (EPA) content was found in chicken from conventional breeding system. The higher total monounsaturated fatty acid content was recorded in thigh meat, while the proportion of polyunsaturated fatty acid was higher in thigh meat than breast. The ratio n-6 to n-3 fatty acids of breast meat was highly lower than the one of thigh meat. The ratio PUFA/SFA was higher in breast than in thigh meat.

Since the PUFA/SFA ratio in thigh and breast meat from free range system was lower than the one of confinement system, consumption of free range indigenous chicken meat can be therefore a better way to improve the consumer's health since dietary intake of unsaturated fatty acids has been shown to reduce the risk of cardiovascular disease.

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Competing interest

The authors declare that no competing interest exit about this article.

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